3998

JPRS: 3998

27 September 1960

POSSIBILITY OF DETERMINING THE MAGNETIC FIELD INTENSITY IN THE OUTER SOLAR CORONA BY EXAMINING THE PROPAGATION OF THE POLARIZED RADIATION OF DISCRETE SOURCES

- USSR -

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NEW YORK 17, N. Y.

F O R E W O R D

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JPRS: 3998

CSO: 4328-D

POSSIBILITY OF DETERMINING THE MAGNETIC FIELD INTENSITY IN THE OUTER SOLAR CORONA BY EXAMINING THE PROPAGATION OF THE POLARIZED RADIATION OF DISCRETE SOURCES

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/Following is a translation of an article by V. L. Ginzburg in the Russian-language periodical Iz-vestiya vysshikh uchebnykh zavedeniy, radiofizika (Report of Higher Educational Institutes, Radio Physics), Gor'kiy, Vol. III, No. 2, 1960, pages 341-342./

The existence of coronal rays, some theoretical arguments, and also the recently discovered anisotropy of dispersed radio waves of coronal heterogeneities /1, 2/ attest to the presence in the outer solar corona of well-regulated magnetic fields. If these fields are connected with the general magnetic field of the sun with an intensity of $H_{\odot} \sim 1$ oersted on its surface (that is, for the reduced distance $\eta = R/R_{\odot} = 1$, $R_{\odot} \simeq 7 \cdot 10^{10}$ cm), then at the distance $\eta = 5 + 20$ from the center of the sun, $H \sim \eta^{-3} H_{\odot} \sim 10^{-2} + 10^{-4}$. However, both the intensity and the configuration, and, therefore, also the derivation of the magnetic field in the outer corona cannot be considered in any sense as established.

In connection with this we shall show, to the extent it is known to us, one still unconsidered possibility for the determination of a field in the outer corona, viz., the presence of the field must reduce to the rotation of the plane of polarization of the radio emissions which pass through the corona. First of all, it is a question of the emissions of the Crab nebula which perforate the corona in the month of June (in principle, certainly, it is possible to also consider other discrete sources and radio transmitters on artificial "planets"). On a 3-centimeter wave the polarization of emissions of the Crab nebula is $p \simeq 7\%$ /3/, and the direction of the pre-eminent polarization is characterized by the positioned angle $= 148 + 149^{\circ}$. Accordingly, on the 10-centimeter wave $p = 3 \pm 0.5\%$ and $\psi = 142 \pm 5^{\circ}$ /4/ (see also /5/). As follows from these works /3-5/ and also from theoretical considerations /6/, polarization is diminished on the longer waves. Therefore it will be scarcely possible to work with waves essentially longer than 10 centimeters.

In the corona (in the plane of the solar equator) the electron concentration /7/ is $N \sim 7 \cdot 10^4$ el $\cdot$ cm^{-3} when $\eta = 5$, $N \sim 10^4$ el $\cdot$ cm^{-3} when $\eta = 10$, and $N \sim 2.5 \cdot 10^3$ el $\cdot$ cm^{-3} when $\eta = 20$. Therefore when $\eta = 5 \div 20$, we have: $\omega_0^2 = 4\pi e^2 N/m = 3.18 \cdot 10^9 N \sim 2 \cdot 10^{14} + 8 \cdot 10^{12}$ sec^{-2} and $\omega_H = \frac{eH}{mc} = 1.76 \cdot 10^7 H \sim 10^5 + 10^3$ sec^{-1} (see above the estimates of H). At the same time, the frequency of the radio emission is $\omega = 2\pi c/\lambda \sim 2 \cdot 10^{10}$ sec^{-1} when $\lambda \simeq 10$ cm. Under such conditions it is possible to consider the expansion of the radio waves as "quasi-linear" practically under all α angles between the field H and direction of the wave standard /6, 8/. With this difference, the exponent of the refraction $n_\pm$ for normal waves which are polarized circularly (with a direction opposite to the rotation of the electric vector) is equal /see Note/ to $\Delta n = \frac{\omega_H \omega_0^2}{\omega^3} \cos\alpha = \frac{5.6 \cdot 10^{16}\, HN \cos\alpha}{\omega^3}$.

The reversal of the plane of polarization of the emission with the passage of the layer of plasma is equal to $\Delta\psi = \frac{\omega}{2c} \int \Delta n dl \simeq \frac{0.93 \cdot 10^6}{\omega^2}$ $HN \cos\alpha\, dl$, where the integration is reckoned along the ray, which in this instance it is possible to consider as rectilinear.

/Note: It has been taken into account that in the observed conditions $|n_\pm - 1| \ll 1$./

Assigning as a function $N(\eta)$ and choosing a determined model for the field (for example, considering the field as dipole), it is possible to calculate the value $\Delta\psi$ depending upon the position of the discrete source. Therefore, by measuring $\Delta\psi$ during the period of "eclipse" of the source of the corona, it is possible, in principle, to obtain valuable knowledge about the field H, if the angle $\Delta\psi$ is sufficiently great and reliably determinable /see Note/. For an estimate we shall suppose that $\Delta\psi \sim \frac{10^6\, HNL \cos\alpha}{\omega^2}$, where L is a certain effective length of travel. Then when $\eta \simeq 5$ ($H \sim 10^{-2}$ oersted, $N \sim 10^5$ el $\cdot$ cm^{-3}, $\cos\alpha \sim 1$, and $L \sim \eta R_\odot \sim 3 \cdot 10^{11}$ cm), the angle $\Delta\psi \sim 60^\circ$. When $\eta \simeq 10$ ($H \sim 10^{-3}$ oersted, $N \sim 10^4$ el $\cdot$ cm^{-3}, $\cos\alpha \sim 1$, $L \sim 10 R_\odot$ cm) $\Delta\psi \sim 1^\circ$. According to their character, these estimates are close to the maximum, if the intensity of the field does not exceed the acceptable. This is fully possible, and thus, even when $\eta \simeq 10$, the considered method can give positive results. This is still more probable with respect to the area of lesser distances η (especially when $\eta \simeq 5$), if the mean value of $\cos\alpha$ along the ray of vision is not very small by virtue of an unfavorable configuration of the field. A sufficiently strong dependence of the angle

$\Delta\psi$ on the frequency ω opens additional possibilities of separation of the considered effect during work on several frequencies.

/Note: We notice that the widening of the angular dimensions of the source connected with the dispersion on the coronal heterogeneity are proportional to λ^2 and therefore in the centimetric diapason are negligible /1, 9/. On the other hand, the finiteness of the dimensions of that same source (the angular dimension of the Crab nebula $\sim 5'$) must lead to some distortion of the polarized picture, for example, by virtue of the dependence of $\Delta\psi$ on η. This effect, however, is more quickly nonexistent./

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